Fuel Chemistry and Cetane Effects on HCCI Performance, Combustion, and Emissions

presentation for DEER 2005

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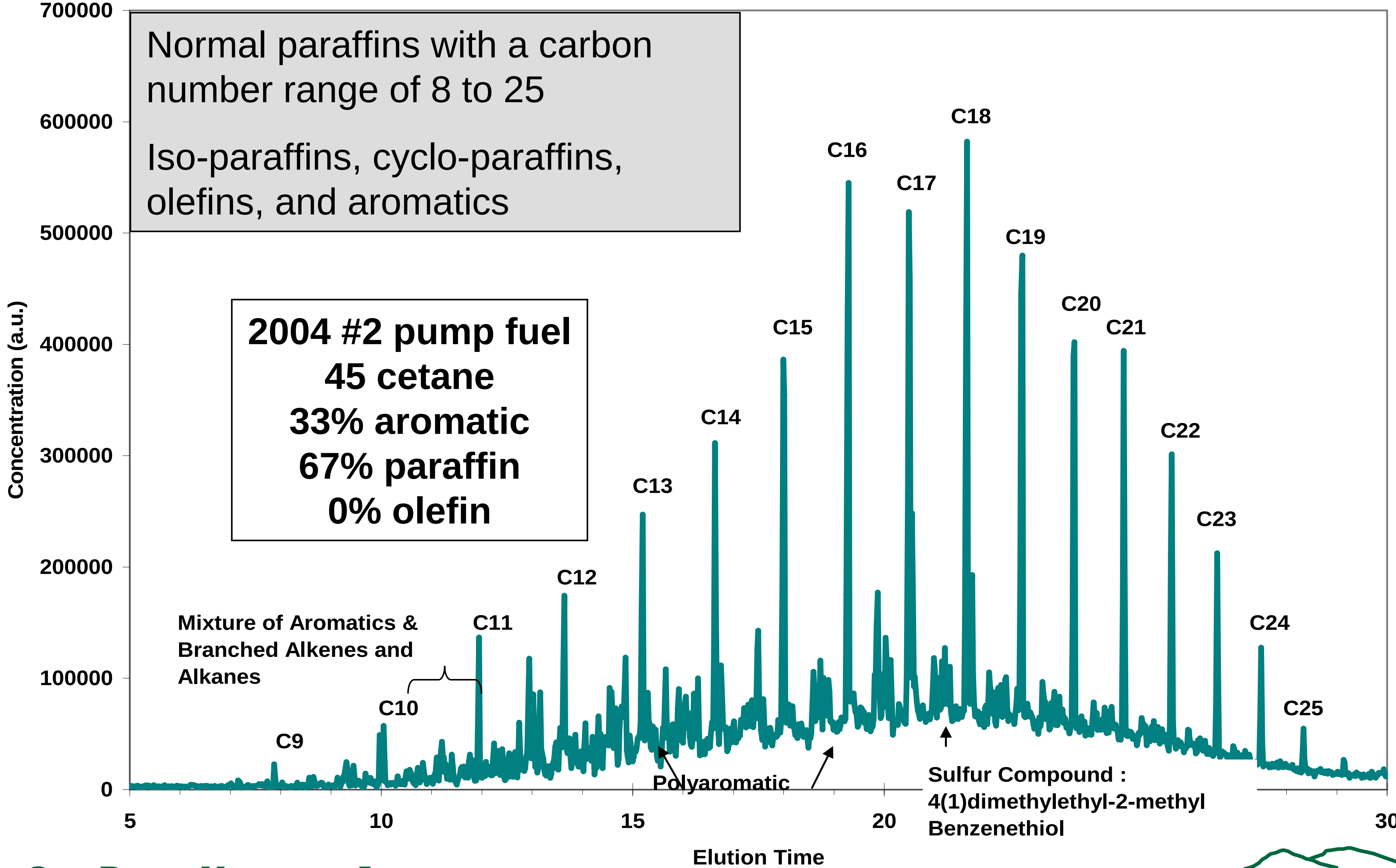
Outline of talk

- Purpose of research
- Engine and experimental procedure
- Results
- Conclusions
- Future work
- Acknowledgements

Purpose of research

- **To provide simple comparisons of the performance of diesel range fuels differing in properties and chemistry in HCCI combustion**
  - **Current study covers commercial fuels**
    - **cetane range of 40 to 73**
    - **aromatics range of 0% to 33%**
    - **includes 100% biodiesel and Fischer-Tropsch fuels**
  - **A second study covers diesel secondary reference fuels**
    - **18 to 76 cetane**
    - **will be presented at SAE HCCI Symposium**

Example diesel fuel composition (GC/MS)



15 fuels evaluated

10 Commercial fuels

- 2004 fuels
- 2007 fuels

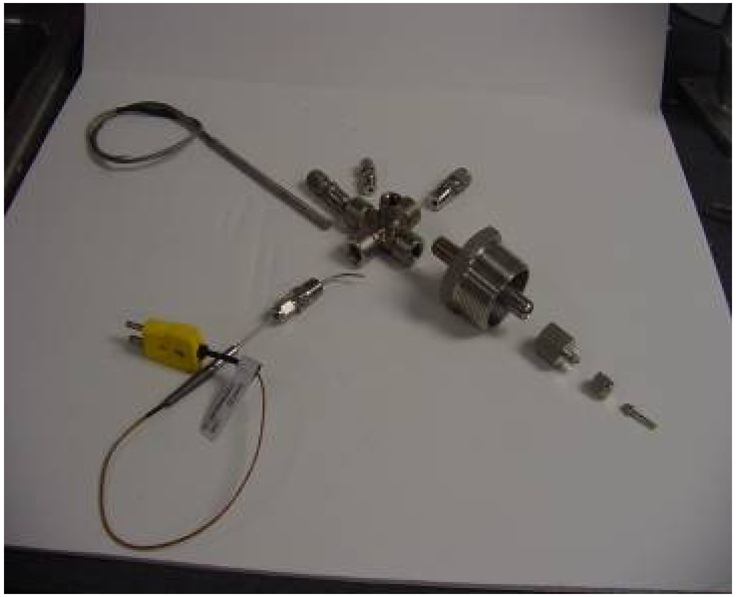
- 5 diesel secondary reference blends
- Cetane range
  - 41 to 73
- Aromatics range
  - 0 to 33%

Fuel	Cetane	Aromatics (%)
A (2007)	45.4	23.5
B (#2 Cert)	47.9	30.5
C (2004)	47.9	15.7
D (2007)	50.5	12.0
E (2007)	50.5	26.4
F (2007)	50.5	32.8
G (2007)	50.5	29.9
H (B100D)	53.2	0
I (California)	53.6	21.4
J (FT)	73.0	0.9
K (37%T/63%U)	40.7	15.8
L (46%T/54%U)	46.7	15.0
M (54%T/46%U)	50.5	14.4
N (63%T/37%U)	53.6	13.6
O (72%T/28%U)	60.7	13.0

Engine used for experiments

- Based on Hatz 1D50Z
  - Single cylinder, air cooled
  - 2 valve, naturally aspirated
  - 517 cc, 97 mm bore, 70 mm stroke
  - Selected modifications made to engine
    - 10.5 C/R
    - Port fuel injection with heated atomizer
    - Intake air heater

Heated atomizer



- Standard tube fittings
- 400 watt cartridge heater
- Slight air purge
- Operated at 375 deg.C
- Mounted between air heater and intake port
- Fuel controlled by laboratory metering pump
- Provides very uniform fuel mixing

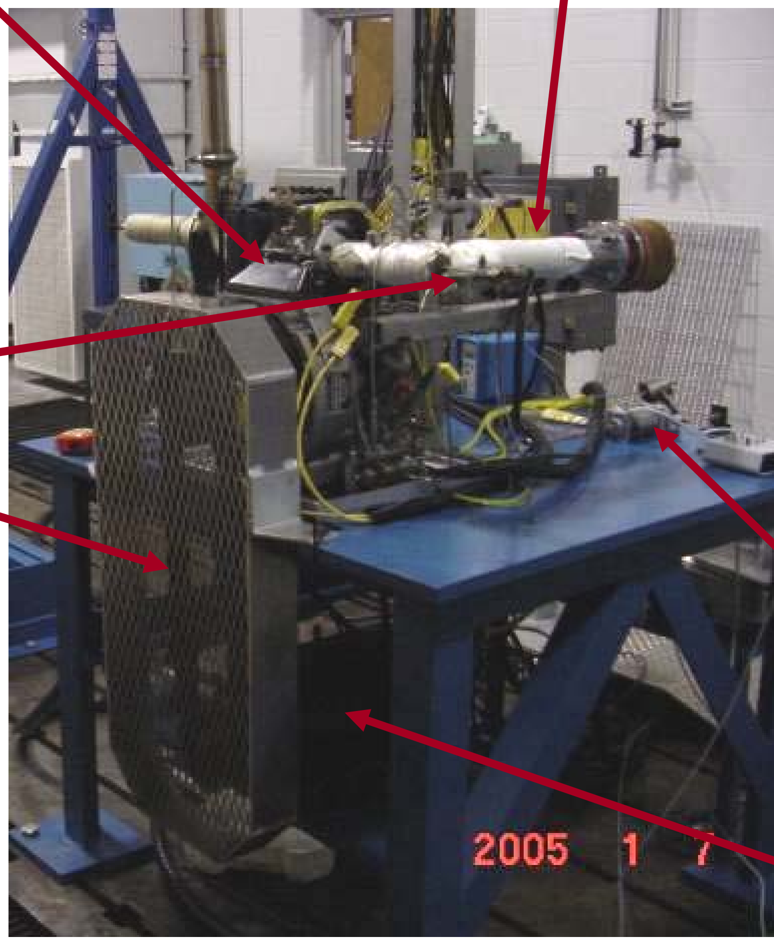
Engine and test stand

ENGINE

INTAKE AIR HEATER

ATOMIZING INJECTOR

BELT DRIVE



METERING PUMP

INDUCTION MOTOR

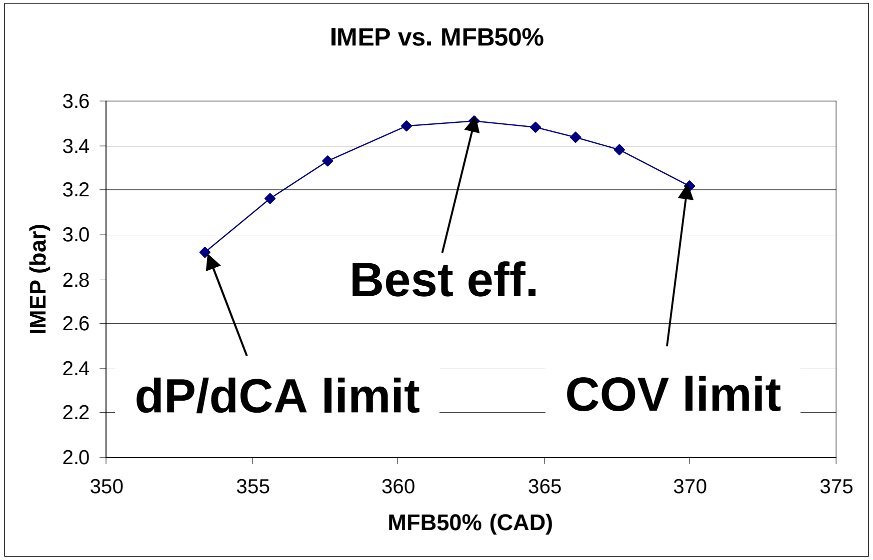
MODIFIED PISTON WITH SPHERICAL COMBUSTION BOWL

Experimental procedure

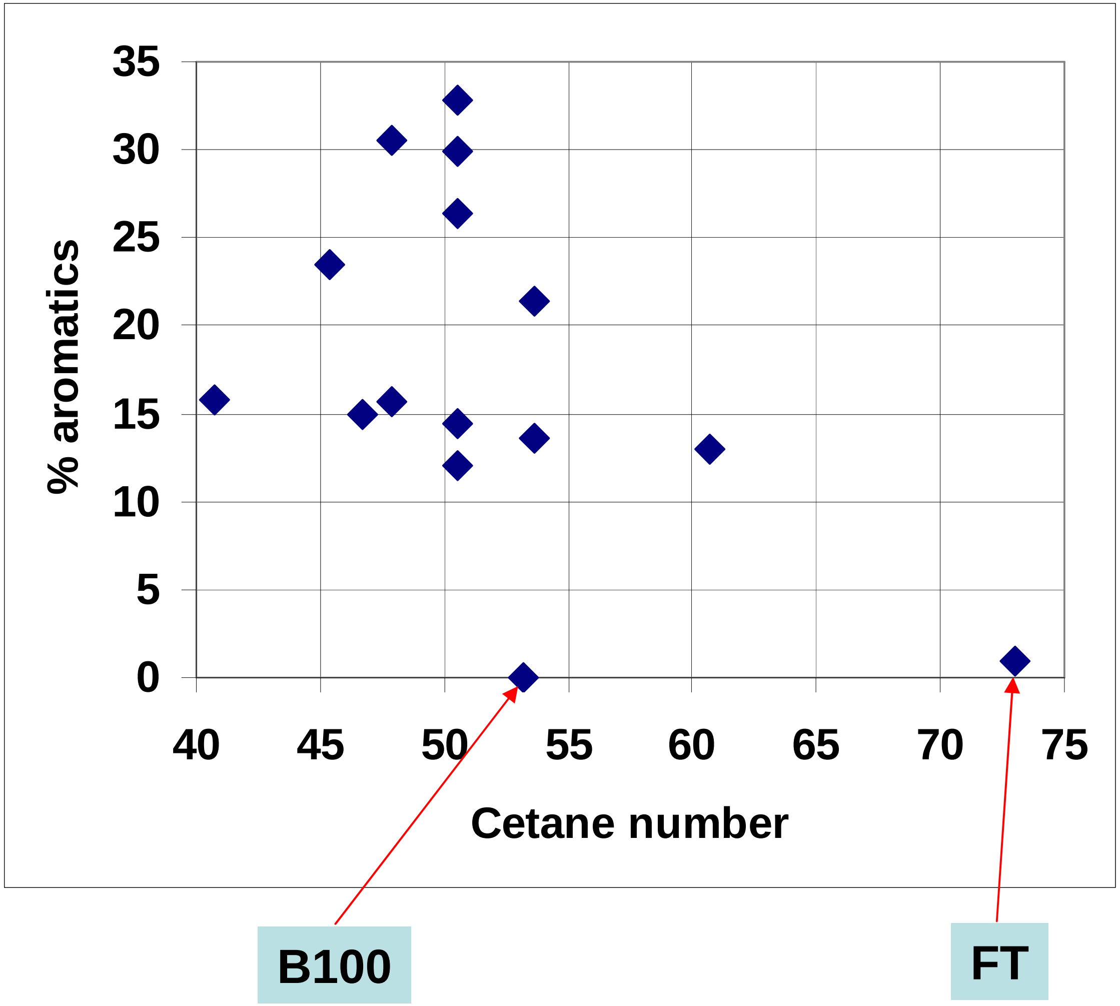
- **Intake temperature used to alter combustion phasing**
- **MFB50 correlates best to block temperature and Φ**
- **Combustion phasing bounds established**
  - **Retarded timing limited by COV IMEP of 10%**
  - **Advanced timing limited by rate of pressure rise of 25 bar/deg**
- **Point of best efficiency used for all comparisons**

Operating Conditions

- **1800 RPM**
- **Stock valve timing**
- **~3 bar net IMEP**
- **15 mL/min fuel flow**
- **$0.3 < \Phi < 0.46$**



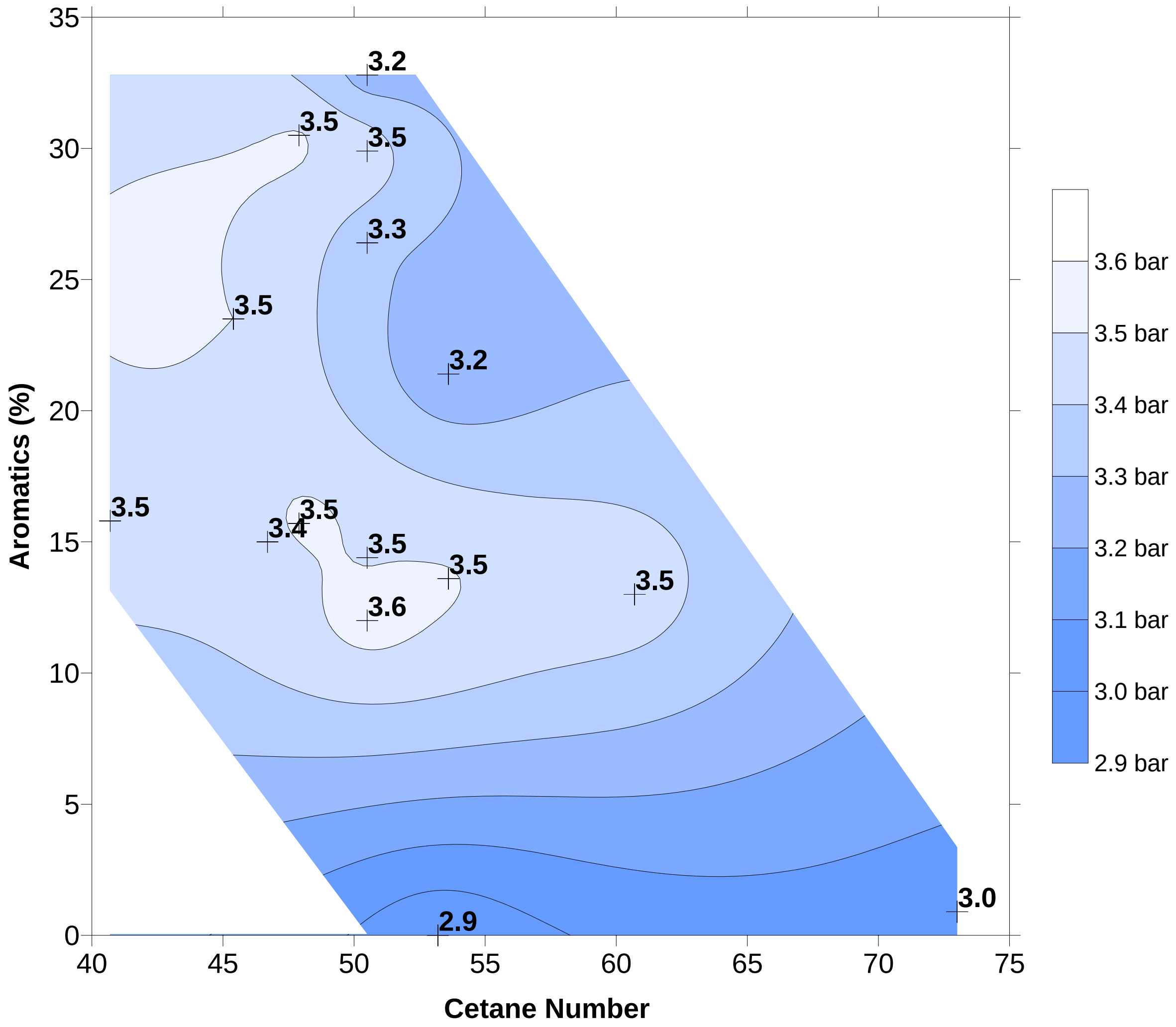
Cetane and aromatic range covered



Olefins ranged from 0.7 to 2.3%

Lower heating values of fuels were within ±2% except B100 and FT, which were lower

Maximum IMEP

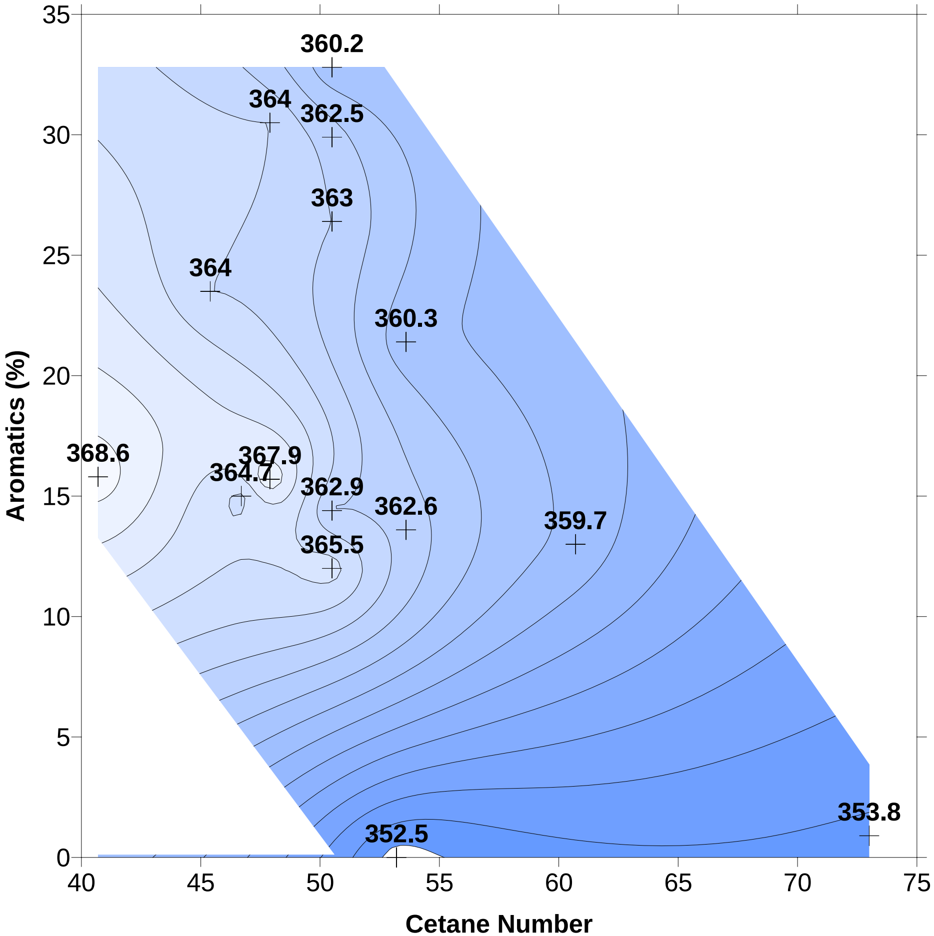


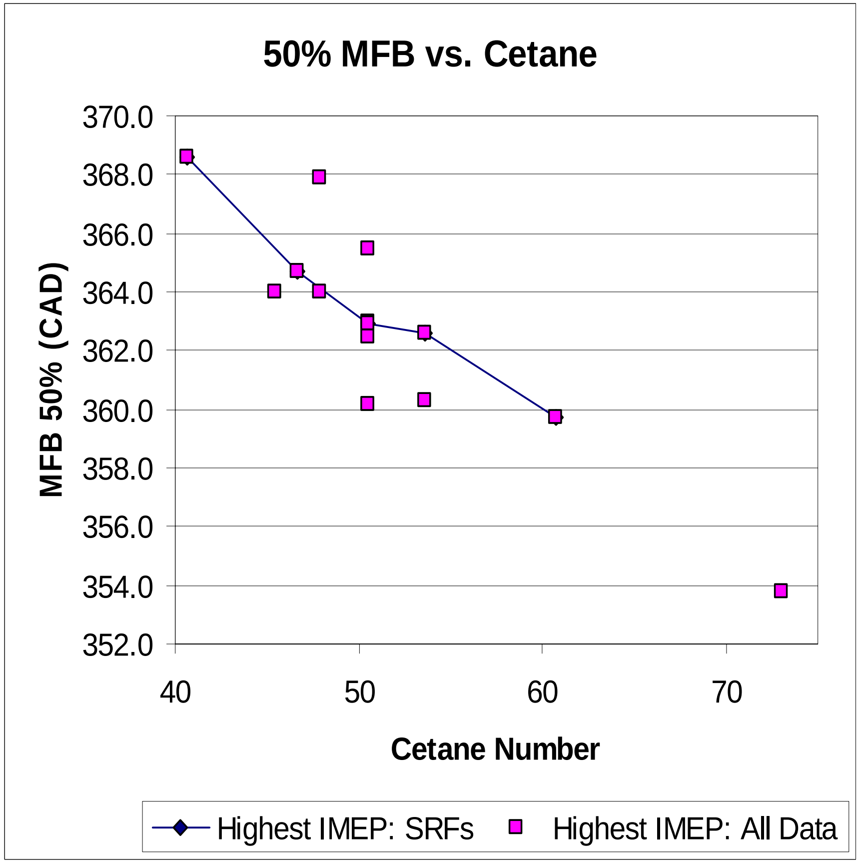
Max IMEP does not appear to depend in cetane or aromatics

B100 and FT were lowest

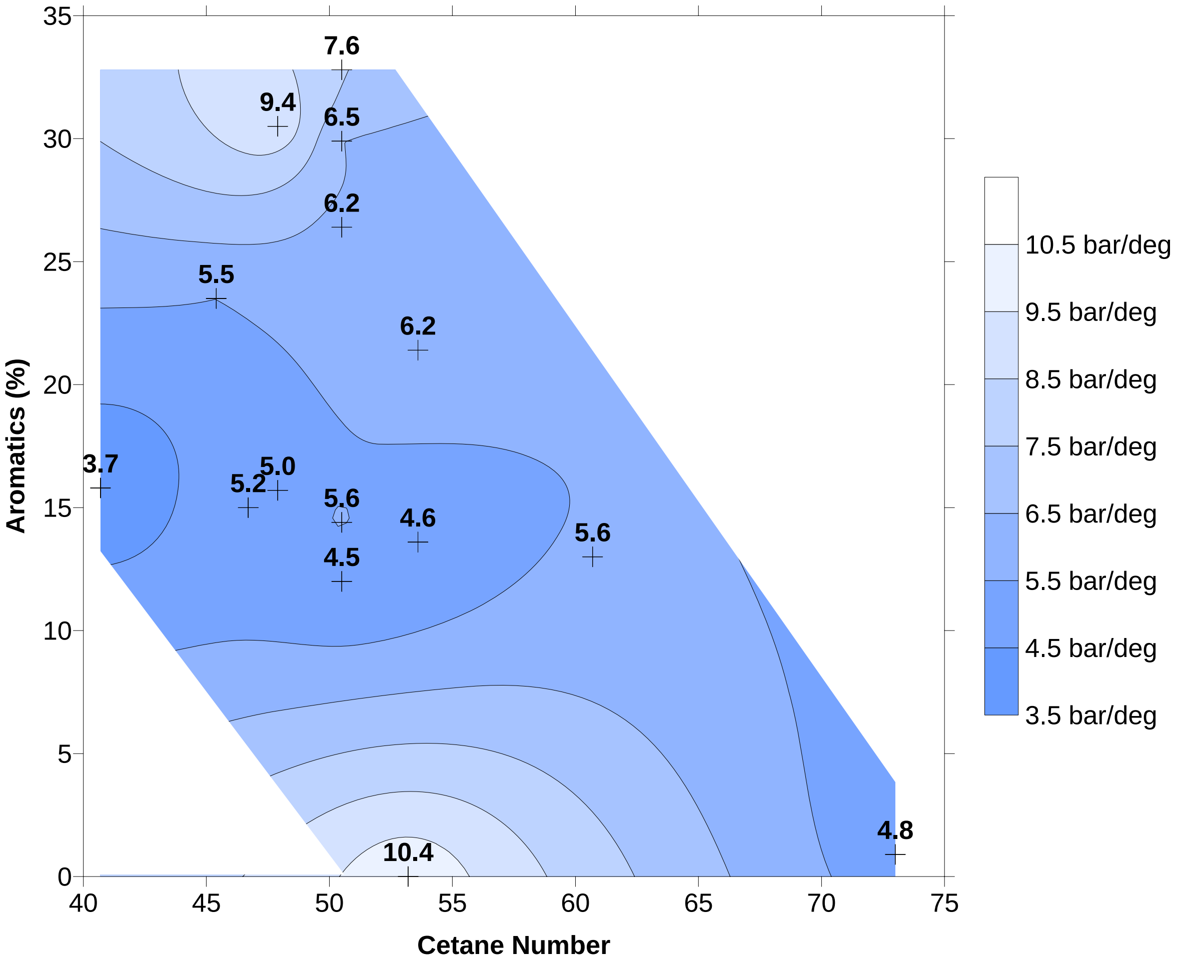
MBT combustion phasing

Combustion phasing correlates with cetane number but not with aromatics. Higher cetane requires earlier MFB50





Maximum rate of pressure rise

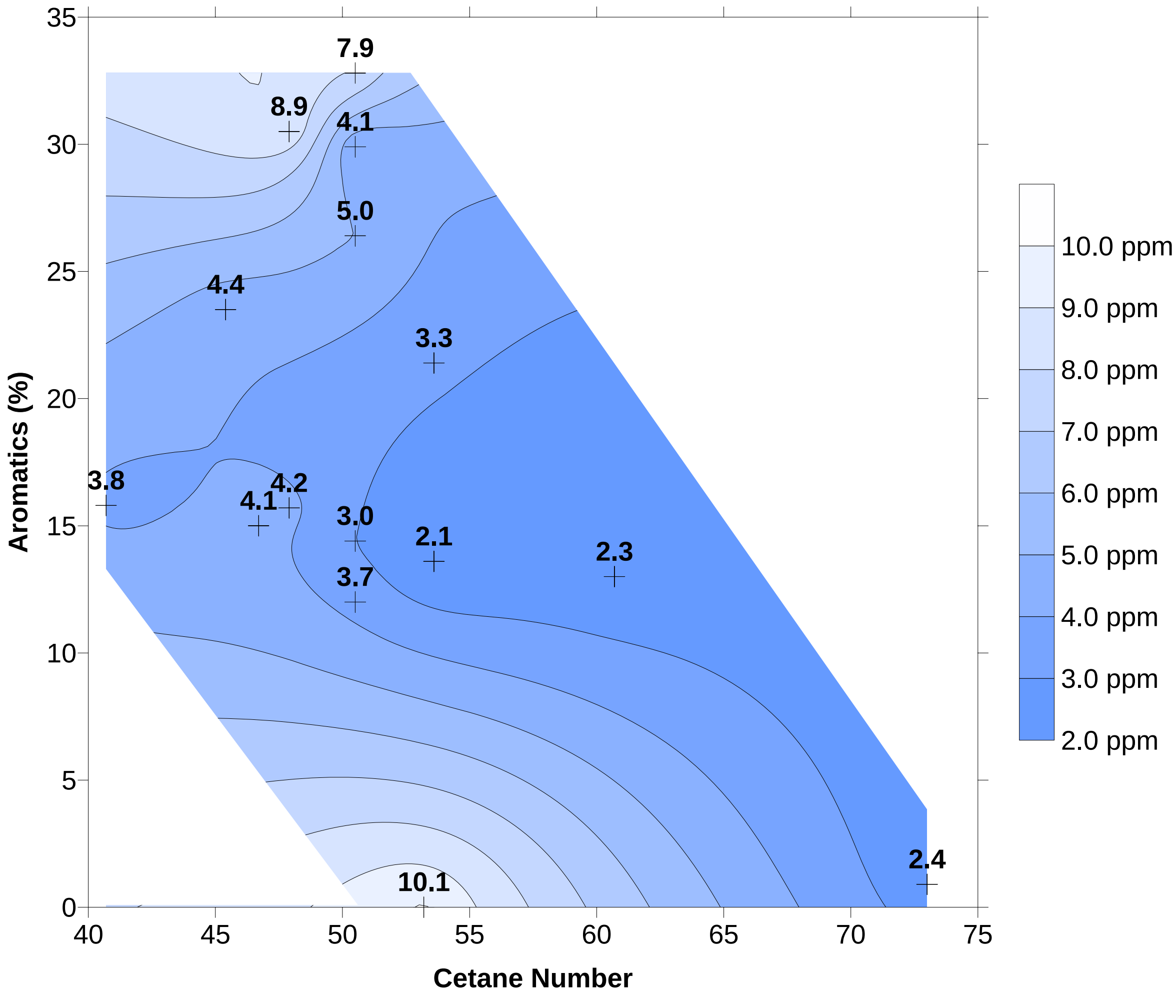


Rate increases with aromatics

Cetane number appears to have little effect

B100 is highest and does not fit trend

NOx emissions

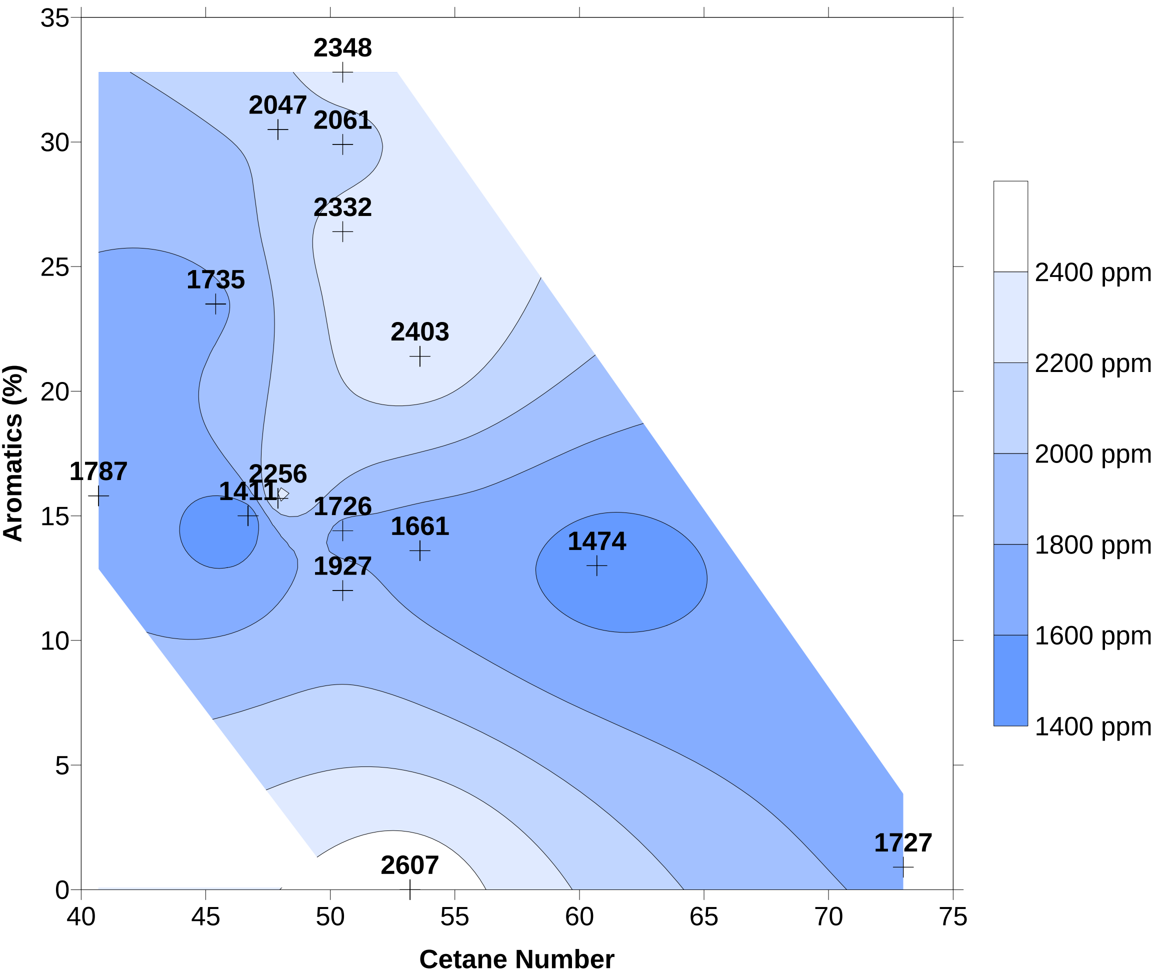


NOx is below 10ppm for all

Highest NOx occurs at high aromatics and low cetane

B100 highest NOx

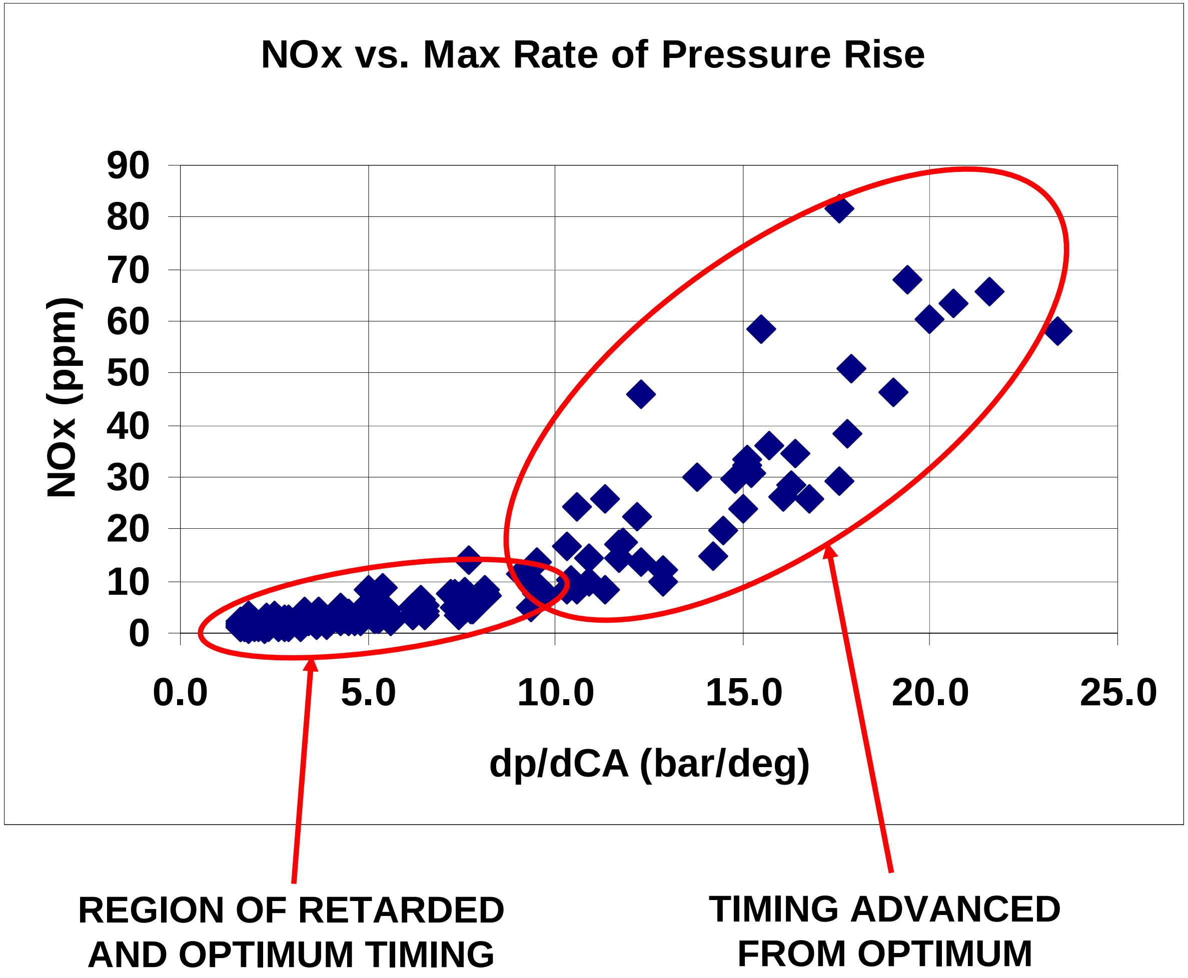
HC emissions



HC increase with aromatics

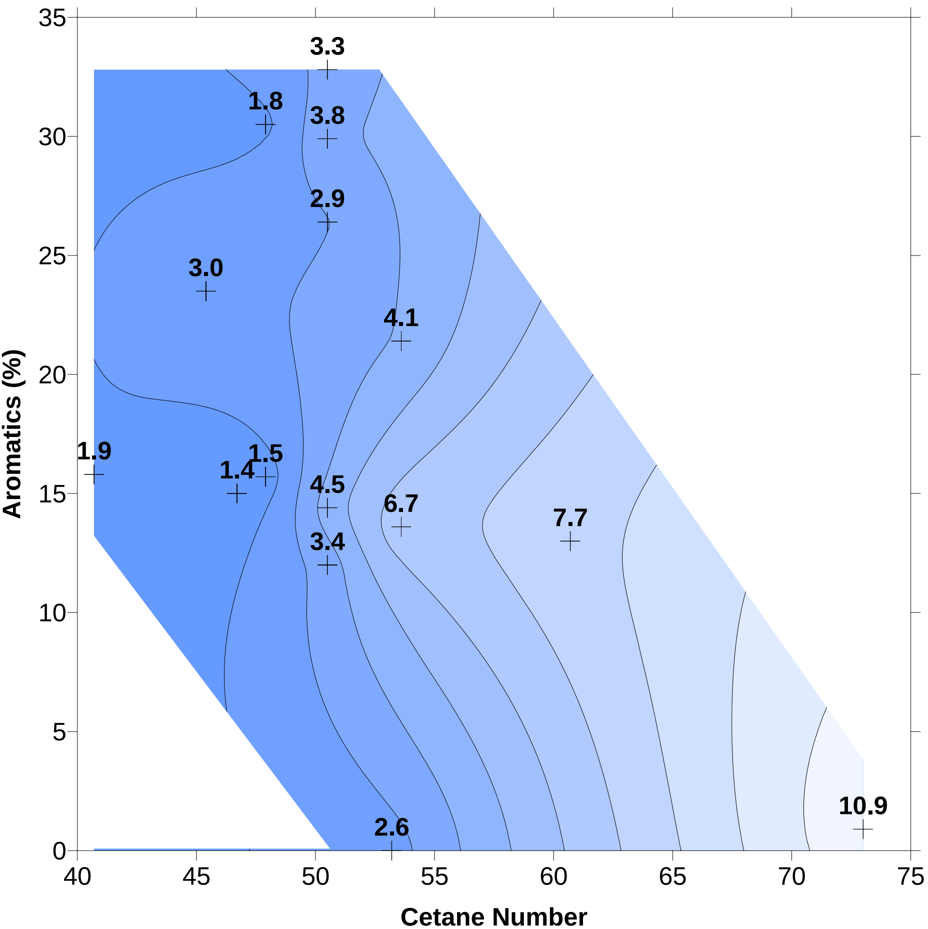
Analyzer and sample train were seriously contaminated by B100

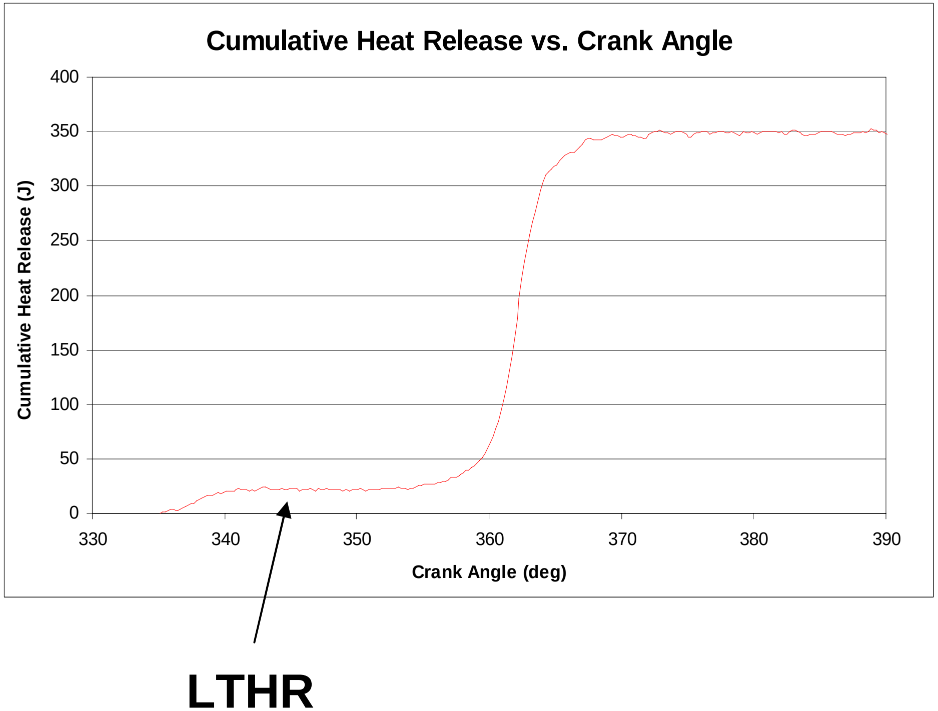
NOx corresponds to rate of pressure rise for all data



LTHR % of total

Low temperature heat release magnitude increases with cetane, no aromatic effect





Summary of results at best timing

VARIABLE	HIGHER CETANE	HIGHER AROMATICS	B100	FT
Max IMEP	----	----	↓	↓
Optimum MFB50	advances	----	Follows cetane trend	Follows cetane trend
Maximum rate of pressure rise	----	↑	↑	----
CA10-90	----	----	↓	Longer (LTHR>10%)
COV IMEP	----	----	----	----
NOX emissions	↓	↑	↑	Follows cetane and aromatic trend
HC emissions	----	↑	↑	↑
CO emissions	----	----	↑	----
LTHR rate	↑	----	↓	Follows cetane trend
LTHR % of total HR	↑	----	↓	Follows cetane trend
LTHR-HTHR spacing	↓	----	↓	Follows cetane trend

Conclusions

- Diesel fuels of 41 to 73 cetane and 0 to 33% aromatics were successfully operated in an HCCI engine at 3.5 bar and 1800 rpm
- B100 operated but produced high HC emissions and did not fit other trends of the fuels
- Heated atomizer worked for port fuel injection of diesel fuel
- Much of fuel behavior can be explained by cetane number
- Aromatics did affect rate of pressure rise, NOx, and HC

Future work

- Apply statistical analysis to data to further understand trends and significance
- Continue fuel studies
  - Oxygenate and bio-diesel blends
  - Cycloparaffin and aromatic study
  - Separate effects of intake temperature and fuel/air ratio to gain better ability to control engine. We are also considering EGR, throttling, VVT, and pressure boosting in future builds
- Continue related work with gasoline range fuels and spark augmented HCCI

Acknowledgements

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- Fuel samples were analyzed by Southwest Research Institute
- FT fuel was supplied by NREL